Remarks

This Preliminary Amendment cancels without prejudice claims 1 to 9 in the underlying PCT Application No. PCT/DE03/00526, and adds without prejudice new claims 10-18. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.125(b), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(ii) and §1.125(c), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

The underlying PCT Application No. PCT/DE03/00526 includes an International Search Report, dated August 22, 2003. The Search Report includes a list of documents that were uncovered in the underlying PCT Application. A copy of the Search Report accompanies this Preliminary Amendment.

It is asserted that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,
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SENSOR, CONTROL UNIT, AND METHOD FOR MONITORING AT LEAST ONE SENSOR

~~Background Information~~ Field of the Invention

The invention ~~proceeds from~~ generally relates to a sensor and a control unit and a method for monitoring at least one sensor ~~according to the species defined in the independent claims~~.

~~Advantages of the Invention~~ Summary of the Invention

The sensor according to the present invention and control unit according to the present invention and method for monitoring at least one sensor according to the present invention having the features of the independent claims have the advantage that a differentiated fault pattern can be transmitted with a specific fault message to the system -- i.e. to the control unit -- and an appropriate reaction can occur, while preventing every fault in a sensor from having the consequence that the sensor signal as a whole must not be used, or that the system identifies a permanent sensor fault and therefore a system defect. Disruptions that do not denote lasting sensor damage, and possibly are even attributable to infrequent but possible operating states, can therefore be not too severely punished. Examples of this are the incoupling of electromagnetic interference, and vibrations due to hammer blows. The performance or sensitivity of the system is thereby improved, and the probability of a control unit field failure is reduced. The invention in particular makes it possible, with adaptation and application to the respective target control unit and vehicle, to react better to specific

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differing system requirements and customer requirements in terms of triggering parameters and fault management.

This allows on the one hand an increase in the performance and robustness of the overall system, and on the other hand a reduction in field failure fates, since with the more in-depth fault pattern detection not all fault patterns must be deemed total failures. The invention is additionally advantageous because fault discovery and optimization can be facilitated in the development and testing phase of a restraint system. Application of the invention is also possible and advisable, however, in other automotive sectors in which sensors are used, in particular in vehicle dynamics control and in navigation.

~~The features and refinements set forth in the dependent claims make possible advantageous improvements to the sensor, control unit, and method for monitoring at least one sensor recited in the independent claims.~~

It is particularly advantageous that the status bits indicating the fault modes are constituted from different sensor-internal monitoring mechanisms, and remain in existence only until a conclusion is drawn as to the operating state belonging to the fault state. The time information for each individual fault mode is thus also usable for system-side application of the sensor. This permits an accurate analysis of the fault, achievable using a so-called look-up table. The fault pattern transmitted from the sensor to the control unit can then be evaluated accordingly in the processor of the control unit. It is thereby possible, in particular, for the control unit to detect whether the fault is permanent and how serious the fault is.

It is especially advantageous that the fault pattern is

transmitted digitally in an eight-bit word, here given the abbreviation MONI, in a 16-bit frame. The MONI word can have different fault indications written to it using different read instructions. The number of transmittable fault modes can thereby be increased. In this word, the fault type or modes are identified by flags. A variety of fault modes and unusual operating states that have been detected are thus indicated by way of this word. Fault modes indicate that at least one sensor operating parameter is outside a predefined range.

In the context of this monitoring, advantageously at least one phase-lock loop of the sensor and/or at least one control voltage is monitored in terms of a predefined range, and/or the output values of at least one analog/digital converter are monitored in terms of a predefined range, and/or the input and/or output values of at least one digital/analog converter are monitored in terms of a predefined range, and/or the dynamic limits of at least one capacitance/voltage converter are monitored in terms of a predefined range, and/or at least one offset controller is monitored in terms of a predefined range, and/or at least one common-mode controller is monitored in terms of departure from a predefined range, and/or at least one variable representing a sensor oscillation is monitored in terms of a predefined range, and/or impermissible values of at least one counter are monitored as defined. When a fault or an unusual operating state is detected, a respective value is set in a respective register, i.e. a fault register is occupied by a logical "1". When that fault or unusual operating state is no longer detected, the respective register is then reset, i.e. a logical "0" is once again set.

When at least one value that denotes a fault is set to "1", another value is also set to one. This makes it possible to indicate, by way of a single bit or flag, whether any sensor-internal fault has been identified. This flag is

transmitted as status information along with every regular sensor output value transmission. If necessary, i.e. in the event the summarizing value indicates a fault state, the detailed fault pattern can then be requested by way of the available read instructions. This procedure of requesting as necessary saves transmission and processing capacity. The allocation of read instructions numbered 1, 2, etc. to the fault information is defined in the MONI word. Two read instructions are used here, i.e. two eight-bit words of fault information can be indicated.

It is additionally advantageous that the sensor itself is disposed inside the housing of the control unit. SPI (serial peripheral interface) lines are then preferably used to interconnect the sensor (via the digital interface) and the processor of the control unit.

~~Drawing~~ Brief Description of the Drawings

~~Exemplary embodiments of the invention are depicted in the drawings and will be explained in more detail in the description below.~~ The present invention will be described in greater detail with reference to the following drawings wherein:

~~The figures show:~~

~~Figure 1~~ Figure 1 shows a block diagram of the sensor according to the present invention in a control unit according to the present invention~~, and~~.

Figure 2 shows a data telegram according to the present invention.

Detailed Description of the Invention

Rotation rate sensors, like other sensors as well, are being used more and more in electronic restraint systems for passive vehicle safety. Rotation rate sensors are core components for the detection of rollover processes and related accident processes, for example soil trip.

Some of the sensors used in restraint systems possess a sensor-internal monitoring function. A fault or malfunction state resulting from a wide variety of causes can, when it is identified, be reported by way of a logical signal (fault, no fault), in a context of analog sensor interfaces, to the system, to a sensor platform, to a control unit that is generally a microcontroller, or to a safety semiconductor.

Digital sensors offer the capability, relatively easily implemented in technical terms, of transmitting various faults and malfunction states to the system by way of permanently assigned bits in data words. Each bit has associated with it a fault flag, which in turn is associated with a sensor-internal circuit block or a sensor-internal monitoring variable or measured variable. The sensor-internal monitoring function generally responds when one of the various sensor-internal control voltages or control variables being monitored enters the limits of its respective dynamic range or is beyond design-related value ranges, or when offset values are outside permissible ranges, or when a phase-lock loop drops out of synchronization, or when counters are found to have an overflow or impermissible values. Monitoring is generally performed by way of window comparators or by evaluating the analog/digital converter output or the digital/analog converter input word. There are thus a wide variety of causes in terms of the sensor evaluation circuit function blocks.

Possible causes of malfunction or fault states:

In rotation rate sensors used in automotive systems, vibrational or mechanical disturbance sensitivity is a matter of functional principle and is a characteristic property that must be accounted for in the sensor application. If there is no mechanical damping, the performance of these systems is limited. A mechanical damper assemblage means a considerable additional outlay in terms of development, cost, and production. Impacts or severe vibrations can disrupt the sensor element so much that the sensor-internal control systems can no longer engage for a certain period of time, and the sensor ends up outside its specified functional range. Further possible disturbances are, for example, incoupled electromagnetic interference. Faults in the sensor itself or in the application wiring can likewise impair system operation. The effects differ depending on the rotation rate sensor fault and the kind of disturbance, and also depending on the application environment of the sensor, i.e. the wiring and circuit board and the vehicle construction.

The rotation rate sensor monitoring function has hitherto been used on the system side only for basic fault detection, i.e. is the sensor OK or not. As regards its reaction, the restraint system at most distinguishes by way of the duration of the fault message whether or not a failure of the rotation rate sensor exists. That absent, an application in terms of coordinating the respective system reaction to the various fault messages does not take place.

Since no classification of different fault patterns is performed on the system side, and the application environment also is not incorporated, the principle of "assuming the worst" must be invoked. When the monitoring function identifies a state as faulty, the consequence is that the sensor signal must not be used, or that the system concludes that a permanent sensor fault and therefore a system defect

exists. Malfunctions that do not signify lasting sensor damage and are possibly attributable to infrequent but possible operating states are therefore generally punished too severely. This limits the performance or sensitivity of the systems, or increases the probability of a possibly unnecessary control unit field failure.

According to the present invention, a fault pattern that contains the combination of different fault modes is therefore transmitted from the sensor to the system, preferably a processor of the control unit, thus conveying to the system accurate information about the nature and cause of the fault. An appropriate reaction by the system to that fault is then therefore possible.

The fault patterns that occur in response to various fault and malfunction causes are already determined in the development and application phase of restraint system electronics systems. With the availability of a look-up table, the system can react properly to the particular fault pattern.

A practical prerequisite for implementation of the invention is a digital sensor interface. Only with this can a large number of different faults and malfunction modes or patterns, as well as combinations thereof, be transmitted to the system with reasonable outlay. The bidirectional SPI (serial peripheral interface) is used here as an example of an interface. In this context, for example, two instructions RD_MONITOR_I and RD_MONITOR_II are provided for reading out the various fault modes, the modes themselves being identified by way of flags in the MONI word transmitted back in each case. The word having eight zeroes, for example, means here that the monitored sensor parameter is within specified operating ranges, and an unusual operating state does not exist. The following faults can be indicated by coding:

The capacitance/voltage converter in which the measured variable is mapped by way of the sensor principle into a capacitance or a capacitance change is outside its predefined range; the value at the analog/digital converter in the drive path, which is an oscillating sensor, is outside its predefined range; the phase-lock loop is not synchronized; the offset controller is outside its predefined range; the sum value and/or difference value of the common-mode control circuit in the drive circuit and/or in the detection circuit is outside its predefined range; the amplitude of the sensor oscillation is outside its predefined range. The drive circuit of a rotation rate sensor serves to generate a defined (i.e. usually regulated) oscillating or rotational motion with which, in the presence of a rotation rate, a measurable effect (for example, a deflection of a micromechanical structure orthogonally to that motion) is generated using e.g. the principle of conservation of angular momentum. This effect is measured or sensed, and processed, in the detection circuit.

In addition to these fault indications, an unusual operating state can be indicated if the rotation rate value that is present exceeds or falls below the measurement range of the sensor, and the value must be mapped onto the maximum or minimum value that can be represented.

Figure 1 shows the sensor and the control unit according to the present invention in a block diagram. Located in a control unit 10 is a sensor 1 that is connected via a digital line 6 to a processor 7. Processor 7 is connected via a data input/output to a memory 8. Processor 7 is connected via a data output to the remainder of restraint system 9. A so-called safety semiconductor 11, i.e. a further processor or a monitoring circuit that also evaluates the sensor output values and can influence the enabling of restraint means, can be connected to digital line 6. Located in sensor 1 is a

sensor element 2 for acquiring a measured variable, e.g. rotation rates or rotational accelerations. The sensor element can chiefly be a micromechanical sensor structure in which drive and detection occur capacitatively. Sensor element 2 is connected to a functional and monitoring module 3 where capacitance/voltage conversion, analog/digital conversion of the sensor signal, driving and regulation of the sensor oscillation, and sensor-internal monitoring functions can be implemented. Functional and monitoring module 3 is connected via a data output to a transmitter module 4. Transmitter module 4 is connected to digital line 6, which is embodied here as a so-called SPI (serial peripheral interface) line.

Functional and monitoring module 3 thus also performs monitoring functions in sensor 1. The measured values are conveyed to transmitter module 5. At a cycling rate predefined by the sensor circuit timing cycle, the fault patterns are continuously updated and can be continuously queried. The measured values in sensor 1 are incorporated into this fault pattern.

Figure 2 schematically shows a data frame of the requested 16-bit MISO word, which is subdivided into a first part 12 and a second part 11. The respective fault word 11 (MONI) is transmitted in second part 11. Two fault words, which can be read out using different MOSI instructions, can be transmitted here. This can occur cyclically or only when necessary. That necessity is indicated in the standard rotation rate transmission by setting a bit that indicates an unusual operating state. That bit is set when at least one indicatable fault instance is deemed to exist.

Sensor 1 can also, alternatively, be located outside control unit 10. Instead of only one sensor 1, several sensors, possibly of different kinds, can also be used and monitored.

In addition to the restraint system discussed here, other vehicle systems are also suitable for this invention, for example a vehicle dynamics system or a navigation system.

~~Abstract~~ ABSTRACT OF THE DISCLOSURE

A sensor having a sensor element, and a control unit having a processor, and a method for monitoring at least one sensor, are proposed. A fault pattern is generated within the sensor and is transmitted from the sensor to the control unit in order to enable an appropriate response to the fault pattern by the processor. The fault pattern is preferably transmitted in an eight-bit word. In addition to faults, unusual operating states are also transmitted.

~~(Figure 1)~~